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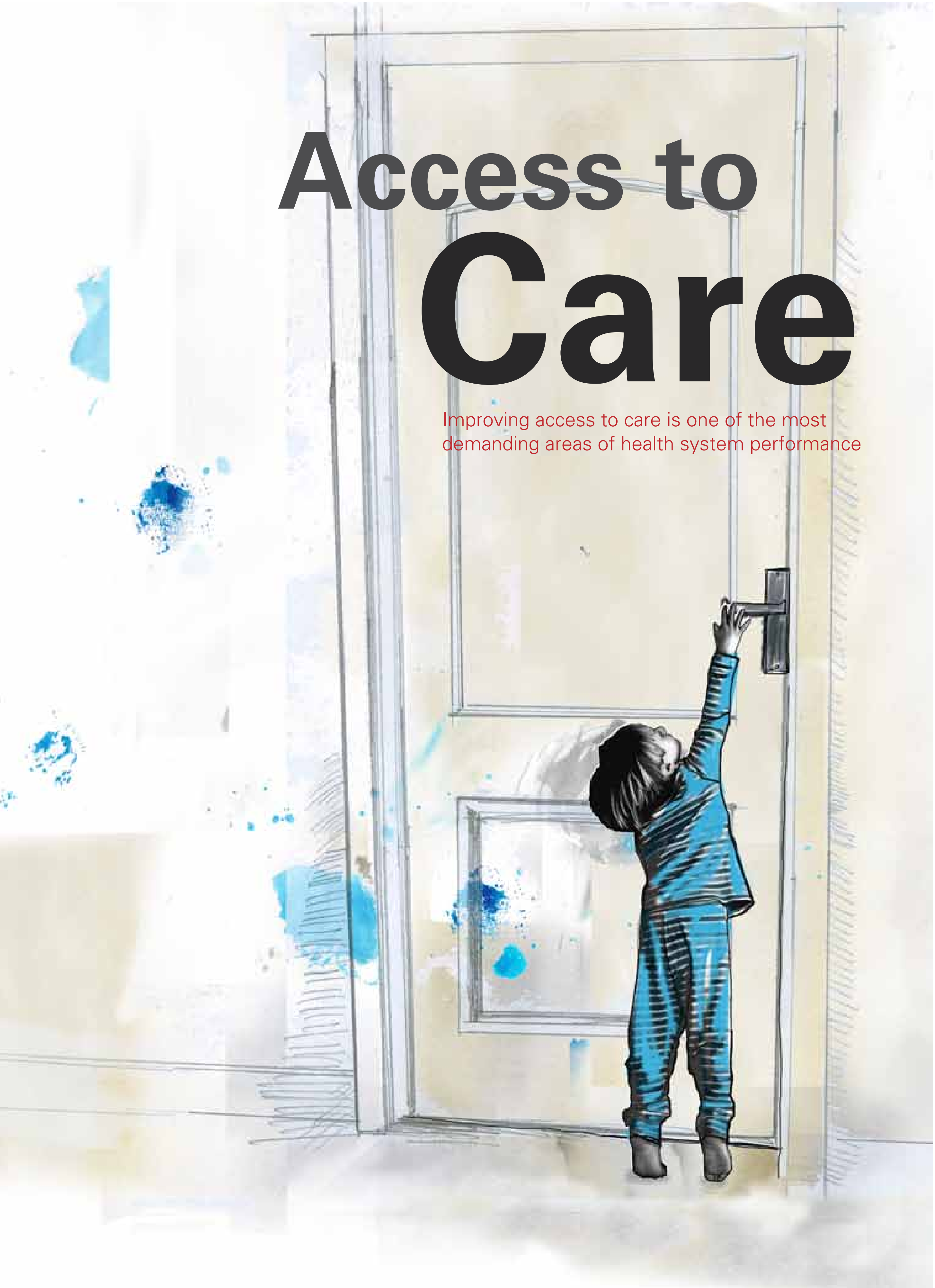

Pediatric Surgical Capacity and Demand: Analysis Reveals a Modest Gap in Capacity and Additional Efficiency Opportunities

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Abstract

The Canadian Paediatric Surgical Wait Times Project conducted an analysis of the alignment between capacity (supply) and demand for pediatric surgery at nine participating hospitals in five provinces. Demand for surgery was modelled using wait list data by assigning patients into monthly buckets of demand ("demand windows") based on the date on which a decision was made to proceed with their surgery plus their surgical wait time access target. Demand was then related to available capacity for various key resources (e.g., operating room availability, intensive care unit [ICU] and in-patient beds). The results indicate a small and not insurmountable gap of 8.5–11% in pediatric surgical capacity at these hospitals. A further capacity issue at many hospitals was ICU occupancy. In addition, an examination of several key performance indicators related to the management of peri-operative resources indicated that opportunities exist for deploying existing resources more efficiently, such as increasing on-time starts and reducing cancellation rates for elective surgery.

Background

Prolonged waits for care are a common issue in publicly funded healthcare systems (Warnock 2005), prompting governments in Canada to make the reduction of wait times a priority. In January 2007, Prime Minister Stephen Harper announced the launch of the Canadian Paediatric Surgical Wait Times (CPSWT) Project to measure wait times for children and youth in need of surgery. The CPSWT Project is the only national effort to measure wait times using standardized access targets developed by surgical expert panels. Access targets were developed for waits one and two: *wait one* is defined as the time from referral to initial specialist consultation, and *wait two* is defined as the time from the date on which a decision is made to proceed with surgery to the surgery date.

Developing access targets for patients' waits and collecting wait times data enable the understanding and management of access-to-care challenges. One potential explanation for excessive wait times is a mismatch between resources and demand for surgery. The purpose of this analysis was to examine the alignment between capacity (supply) and demand for pediatric surgery at nine participating pediatric academic health sciences centres (PAHSCs) in five provinces. This analysis is consistent with the recommendation of the Health Council of Canada, which urges that "jurisdictions should make it a matter of policy to calculate capacity requirements for both elective and emergency cases based on their estimates of projected need" (2005: 7).

Methods for Analyzing Capacity and Demand

Multiple approaches were used to analyze the alignment between capacity and demand for pediatric surgery. These are discussed below.

Wait List Trends

One method for assessing whether a gap in capacity exists is to examine the trend in waiting cases. Fundamentally, surgical queues result from a short- or long-term mismatch between capacity and demand. Specifically, queues can be the result of a past backlog of uncleared demand, an existing and continuing gap between capacity and demand or some combination of the two. If the wait list is stable, the queue is likely the result of a past backlog of uncleared demand that potentially can be addressed with a short-term "surge" in capacity rather than a fixed increase in capacity (Naylor 1991). Conversely, if the number of waiting cases is increasing over time, this indicates an ongoing gap between capacity and demand, and an ever-growing wait list.

Established Principles of Capacity Planning

The principles of capacity planning, as outlined in the healthcare operations management literature (Langabeer 2008; Rhyne and Jupp 1988), were used as a framework for further analyses of capacity and demand for pediatric surgery. The aim of capacity planning is to align capacity with demand, and this is generally achieved through a five-stage process, which is outlined in Figure 1.

Based on this framework, the first step involved the development of a model for estimating demand for pediatric surgery at participating hospitals. In its simplest form, demand is the arrival rate of patients into the queue (Mango and Shapiro 2001). However, modelling demand for elective surgery must account for the fact that patients with different diagnoses have varying maximum recommended wait times (access targets). Therefore, elective surgical demand was measured using each hospital's wait list data by assigning all patients into monthly "demand windows" based on the date on which a decision was made to proceed with surgery plus their surgical wait time access target (for wait two). The access targets used for the creation of the demand windows were the Paediatric Canadian Access Targets for Surgery (P-CATS; Canadian Paediatric Surgical Wait Times Project 2010), developed for over 800 surgical diagnoses by pan-Canadian surgical expert panels. For example, if a patient's decision to proceed with surgery was made on February 1, 2009, and the procedure had an assigned P-CATS access target of six weeks, the patient was assigned to the March 2009 demand window.

Estimating demand using this methodology has several advantages. First, it measures demand in a way that reflects all cases in the queue, both waiting and completed. Second, it considers patients' clinical acuity, as recommended by Zellermeyer (2005). Third, research has shown that where different recommended wait times exist, optimal scheduling is achieved by scheduling lower-priority patients as late as possible without exceeding their wait time target (Patrick and Puterman 2008). Accordingly, the methodology used in this study assigned patients into demand windows based on their last day within target.

The second step in the capacity planning process was to translate this demand into capacity requirements. This was achieved by collecting data on the resources used by each patient on the wait list (e.g., the operating room [OR] time required for completion of the procedure and whether an intensive care unit [ICU] or in-patient bed was required). These data were then aggregated to estimate the capacity requirements for each hospital. For example, the elective OR time required for a hospital was estimated by summing the operating time (and turnover time) for each case in a demand window. Hospitals submitted only aggregated data for analysis.

The third step in the capacity planning process involved an analysis of existing capacity across key peri-operative resources. Participating hospitals identified the resources that drive surgical capacity (i.e., the most likely bottlenecks in the peri-operative process) at their sites via survey. The survey considered resources across the entire peri-operative process, including pre-admission clinics, day surgery units, OR resources and post-operative resources. The most commonly identified drivers of capacity were selected for analysis, including OR availability and ICU and in-patient beds.

Three of the participating hospitals are not dedicated pediatric facilities and share resources with adult patients (e.g., mixed OR time). In these cases, pediatric surgical capacity (i.e., OR availability for pediatric surgery) was estimated by scaling overall capacity based on the proportion of the case load that was pediatric and the average pediatric versus adult case length.

The fourth step involved measuring the gap between capacity and demand by combining (where possible) the estimates of required capacity (from step two) with the analysis of existing capacity (from step

FIGURE 1.
Stages of the capacity planning process

three) into "load percentages." Load percentages relate required capacity to available capacity on a percentage basis. For example, an OR load percentage was calculated by relating the amount of elective OR time *required* in a period to the elective OR time *available* in the same period. A load percentage greater than 100% indicates that the demand for a resource exceeds its availability.

In the final step of the capacity planning process (but exceeding the scope of this article), strategies are developed to eliminate any gaps between capacity and demand. These strategies may include re-engineering processes to deploy existing capacity more efficiently, or adding or shifting capacity and resources (Langabeer 2008).

Analysis of Key Performance Indicators

Provincial ministries of health, hospitals, regional health authorities and non-governmental organizations have identified both insufficient resources and poor management of existing resources as the most common causes of excessive wait times (Sanmartin et al. 2000). Therefore, in addition to an analysis of capacity and demand, data were also collected on various key performance indicators related to the management of peri-operative resources. Key performance indicators commonly collected by participating hospitals were considered and included OR utilization, start time accuracy for the first surgical case of the day, the percentage of pediatric elective surgeries cancelled on the day of surgery and the average lengths of stay of surgical patients. Significant variation in performance indicators may indicate opportunities for hospitals to improve resource management by identifying areas where existing resources can be deployed more efficiently to increase patient throughput (i.e., the number of patients that can be treated in a period of time) without additional capacity.

Standardized definitions were used for the key performance indicators collected (e.g., all hospitals submitted OR utilization data excluding turnover time). Where a hospital's definition for an indicator varied materially from the standard definition, the data were excluded.

Findings

Nine PAHSCs in five provinces participated in this study. All data and findings are based on the period from December 2008 to November 2009, unless otherwise specified. The findings are aggregated across all hospitals.

Wait List Trends

The CPSWT Project wait list was empty at the onset of data collection as only cases with a decision to proceed with surgery date of September 2007 and onward were included. As a result, there was a sharp initial increase in the number of waiting cases added to the CPSWT Project wait list as it became populated. The wait list was deemed to be mature when the rate of increase in waiting cases showed a sharp levelling off, which occurred in May 2008. Therefore, the wait list trend is examined only from this point of maturity, as from this point onward any increase in the wait list may be assumed to be natural (and hence indicative of a gap between capacity and demand).

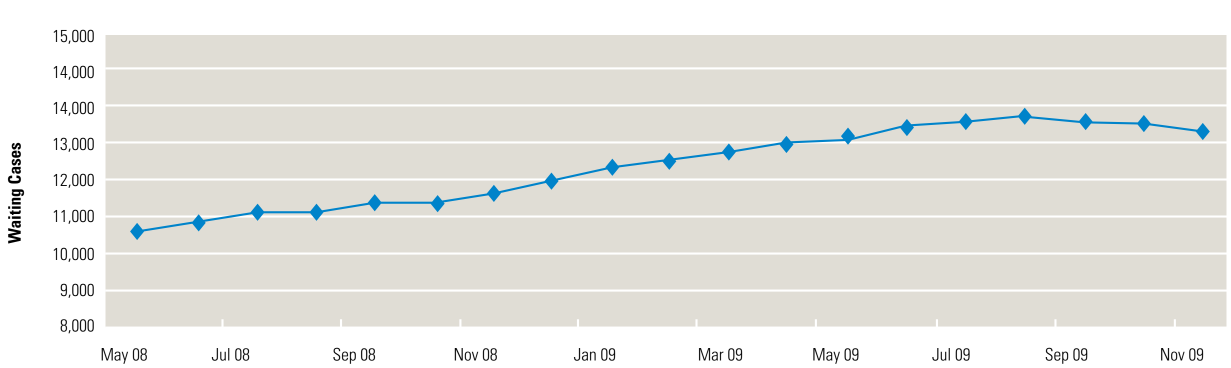
A significant increase ($p < .001$) in the number of elective surgical waiting cases over time was observed at the participating hospitals for the period of May 2008–November 2009 (Figure 2). Eight of the nine hospitals showed a significant increase in the number of elective waiting cases over this period.

Load Percentages

To further analyze the alignment between capacity and demand for pediatric surgery, load percentages were calculated using the capacity planning methodology outlined above.

A case load percentage was calculated relating the demand

FIGURE 2.
Trend in waiting cases from May 2008 to November 2009 at participating hospitals



The trend in waiting cases is shown from the point when the wait list reached maturity (May 2008), which was determined to be the point when the rate of increase in waiting cases levelled off and the wait list became fully populated.

for elective surgical procedures (i.e., the number of cases requiring surgery in a demand window, as outlined above) to the actual elective case volume completed by the hospital in that period. The average case load percentage across all hospitals was 108.5% (see Table 1), with eight of the nine hospitals having case load percentages over 100% for the period analyzed.

To assess capacity and demand for OR time, an OR load percentage was calculated by relating elective OR time *required* by a hospital in a period to the elective OR time *available* at the hospital in that period. The average OR load percentage across all hospitals was 94.4% (see Table 1). An adjusted OR load percentage was also calculated to adjust elective OR time available for 85% utilization. The average adjusted OR load percentage was 111.1% (see Table 1), with seven of the nine hospitals exhibiting adjusted OR load percentages greater than 100%. The monthly variability in the average case load percentage and the average OR load percentage are shown in Figure 3.

ICU and In-patient Beds

Bed occupancy rates, which show the use of beds by measuring the average percentage of time that they are occupied, have been used to examine the relationship between capacity and demand for acute hospital beds (Bagust et al. 1999). The median and range of average ICU and in-patient unit occupancy rates are shown for the participating hospitals in Table 2.

In order to allow for natural fluctuations in demand, 80–85% occupancy has been proposed as an appropriate target for general, short-stay hospitals (Bagust et al. 1999; House of Commons Committee of Public Accounts 2005; Shonick 1972). For both the ICU and in-patient unit occupancy rates, the median value was above the 85% threshold. Five of eight hospitals had an average ICU occupancy rate above 85%, and five of nine had an average in-patient unit occupancy rate above 85%. A significant correlation between the average ICU and in-patient unit occupancy rates at the hospitals was not found ($r = 0.45$, $p = .26$). However, a significant correlation was observed between the OR load percentage and the ICU occupancy rate ($r = 0.74$, $p = .04$).

Key Performance Indicators

Select key performance indicators were also analyzed to assess the efficiency with which existing capacity was deployed. Raw OR utilization data (excluding turnover time between patients) were in the range of 68–81% for all but one hospital and were therefore relatively consistent. Other indicators, however, showed considerable variability across the hospitals, indicating

TABLE 1.
Load percentages for December 2008 to November 2009

	Case Load Percentage	OR Load Percentage	Adjusted OR Load Percentage
Average	108.5	94.4	111.1
Minimum	97.7	56.3	66.2
Maximum	118.8	122.1	143.6

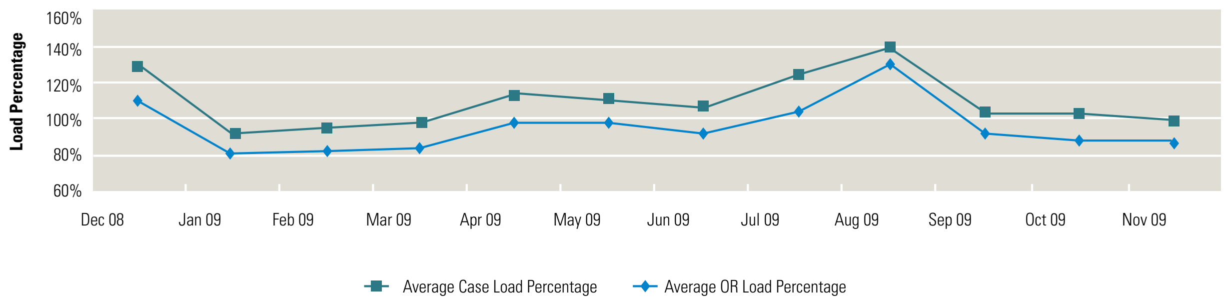
OR = operating room.

TABLE 2.
Average ICU and in-patient bed occupancy rates* for December 2008 to November 2009

	ICU Occupancy Rate (%)	In-patient Unit Occupancy Rate (%)
Median	87.9	86.1
Minimum	43.3	60.9
Maximum	101.4	97.8

*Eight hospitals provided intensive care unit (ICU) occupancy rate data. All occupancy rates are combined surgical and medical rates.

FIGURE 3.
Average case load percentage and average OR load percentage by month



potential opportunities for improving capacity use. Start time accuracy for the first surgical case of the day (which was defined as the percentage of first cases with the patient in the OR at the scheduled start time) ranged from 3 to 58%, with a median of only 25% for six hospitals providing these data. The percentage of pediatric elective surgeries cancelled on the day of surgery ranged from 5.2 to 16.8%, with a median of 6%. Finally, the average length of stay of surgical patients in the ICU ranged from 1.3 to 5.6 days, with a median of 2.8 days; whereas the average length of stay of surgical patients in the in-patient units ranged from 2.7 to 5.3 days, with a median of 3.9 days.

Attempts to reduce wait times and waiting lists simply by adding resources do not always succeed in the long term.

Discussion

Modest Gap in Capacity

The aggregated findings presented above consistently suggest a modest gap in pediatric surgical capacity at participating hospitals. The number of elective surgical waiting cases showed a significant increase over the period from May 2008 to November 2009, suggesting an ongoing misalignment between capacity and demand (see Figure 2). While the number of waiting cases does appear to level off and even decrease slightly toward the end of 2009, this may be due to seasonal effects, as a similar levelling off is observed for one year earlier.

The average case load percentage suggests the need for hospitals to increase their throughput by an average of 8.5% to meet demand. Further, eight of the nine hospitals had case load percentages over 100%, indicating that most would need to increase their case volumes by varying degrees to meet the demand.

An average OR load percentage of 94.4% would appear to suggest that elective surgical demand can be managed in the available OR time, if the time is used efficiently. In reality, however, 100% utilization is not realistically achievable (since it would require a perfect alignment of resources with no disruptions) and, thus, *effective* OR capacity is less than all available OR time. Therefore, an adjusted OR load percentage was also calculated to adjust elective OR time available to 85% utilization (including turnover time between patients), a commonly used benchmark (Stodd et al. 1998). The average of 111% suggests the need for 11% additional OR time on average for these hospitals, or less with improved use of existing OR time. Further, seven of nine hospitals had adjusted OR load percentages over 100%, indicating that most would need either some additional OR time or to improve efficiency (or a combination of both).

The average case load percentage and average OR load percentage displayed significant month-to-month variability (see Figure 3), driven by variability in both capacity and demand. In particular, the increases in the load percentages observed in December 2008 as well as July and August 2009 were largely driven by the fact that most hospitals operate at reduced OR capacity during these months due to holiday-related closures. Variability in demand is driven by both the arrival rate of patients to the wait list as well as their case mix (since they are assigned into demand windows based on their access targets).

The median ICU and in-patient unit occupancy rates were above the proposed 80–85% targets, suggesting the availability of these beds is a significant driver of capacity at many of the hospitals. Moreover, a statistically significant correlation was observed between the OR load percentage and the ICU occupancy rate, suggesting that constrained capacity in the ORs is generally associated with constrained capacity in the ICU as well. The lack of correlation between the ICU and in-patient unit occupancy rates, however, suggests that high occupancy in one unit does not necessarily indicate high occupancy in the other.

Occupancy rates consistently above the 85% target may make it difficult to manage natural demand fluctuations and peak periods, resulting in delays and long wait times for beds (Bagust et al. 1999), and may also increase the rate of hospital-acquired infections (Cunningham et al. 2006). However, other factors also need to be considered in capacity planning. For example, a hospital with a highly variable daily patient census may not even be able to achieve 80% occupancy without creating excessive wait times for beds. Conversely, a hospital primarily handling elective patient admissions may have a relatively constant daily census, in which case a higher target occupancy rate may be appropriate (Shonick 1972). Thus, the 80–85% target should be viewed only as a general guideline.

The observations presented above are broad findings based on aggregated data and, therefore, cannot be applied to individual hospitals. In fact, a few hospitals may not have capacity constraints at all, as suggested by their static wait lists, load percentages below 100% and relatively low bed occupancy rates.

Opportunities for Improved Efficiency

Prior experience, both in Canada and abroad, has shown that attempts to reduce wait times and waiting lists simply by adding resources do not always succeed in the long term (Sanmartin et al. 2000). This is especially true when additional resources are added in the absence of other initiatives, such as those aimed at cleaning up wait lists or improving operational efficiencies. The key performance indicators outlined above showed considerable variation between the hospitals, indicating an opportunity for some hospitals to improve efficiencies within their perioperative processes.

Start time accuracy for the first surgical case of the day has been suggested as a significant indicator of surgical suite efficiency (Zellermayer 2005). If true, the median of only 25% and wide range of 3 to 58% indicate opportunities for more efficient resource use. In addition, frequent same-day surgical cancellations can negatively impact the efficiency of the surgical suite. The wide range in cancellations also suggests opportunities for improvement. While 43% of same-day cancellations were due to medical reasons that may be outside of a hospital's control, 22% were due to patient-initiated factors (such as non-compliance with guidelines, which may indicate inadequate patient education and preparation) and an additional 9% were due to a scheduled surgery exceeding its booked time (suggesting inaccurate scheduling practices). A further 7% were due to the unavailability of ICU and in-patient unit beds.

Research conducted by the UK National Health Service has found that bed unavailability is not necessarily due to bed shortages but may be caused by delayed discharges or patients occupying beds unnecessarily (i.e., patients that could have been treated on an outpatient basis; NHS Modernisation Agency 2001). While the considerable variation in the average ICU and in-patient unit lengths of stay between the hospitals outlined above is partly the result of variations in case mix, it may also be the result of varying practice patterns and discharge rules, suggesting additional opportunities for improving capacity utilization. Disciplined discharge procedures can increase effective bed capacity by ensuring that beds are not occupied by patients who do not require them (Walley et al. 2006).

Study Limitations

This analysis has several potential limitations. First, demand as estimated by the load percentages was measured using each hospital's wait list data (for wait two). However, wait lists can show significant year-to-year variability, and only one year of data was examined in this study. Thus, while all of the above findings consistently point to a modest gap in pediatric surgical capacity, precisely quantifying this gap would require an analysis of several subsequent years of longitudinal data. In addition, the demand for surgery itself may be affected by the wait list through a "feedback" phenomenon. Added capacity and shrinking wait lists may result in lower thresholds for certain elective procedures or specialist referrals, thereby increasing demand (Naylor 1991; Sanmartin et al. 2000). As well, demand is unlikely to be static over time and may vary due to demographic factors.

Second, only those resources that participating hospitals identified as the most critical to overall surgical capacity were examined. However, other peri-operative resources not examined in this study may also impact patient throughput and affect timely access to surgery at some hospitals. These resources should be considered in future analyses to ensure that fixing a capacity shortage in one area does not simply shift the bottleneck elsewhere, as the most constrained resource or stage in the process ultimately determines the throughput of the entire surgical process (Langabeer 2008). For example, increasing OR time will not solve a capacity shortage if there are insufficient surgeons and nurses to use the time or there are insufficient post-anesthesia care beds to support the increased throughput.

Finally, while standardized definitions were used for the key performance indicators collected, minor variations among hospitals likely remained. However, while these variations may have contributed slightly to the range observed in the findings, the variations in definitions were likely small as hospitals adjusted their own internal definitions to conform to the standardized definitions used for this study or, if they were unable to do so, their data were excluded.

Conclusion

In conclusion, the findings presented in this study suggest a modest gap in pediatric surgical capacity at participating hospitals. Most hospitals demonstrate a need for some additional elective OR time or improved efficiency based on current levels of demand. In addition, constrained OR capacity appears to be associated with constrained ICU capacity. The observations presented are based on aggregated findings and, therefore, cannot be applied to individual hospitals.

Hospitals can use the "demand window" framework developed in this study to examine multiple years of longitudinal data to more precisely quantify their gap between capacity and demand. In addition, an examination of several key performance indicators related to the management of peri-operative resources indicated that opportunities exist for deploying existing resources more efficiently. HQ

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